Dual Laser Plasma Photoabsorption Studies Of Gadolinium In The Extreme Ultraviolet Region

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DCU

Talk outline

- Introduction/motivation
- Dual Laser Plasma (DLP) Photoabsorption
- Previous Results for Sn
- Gd I absorption spectrum
- Summary

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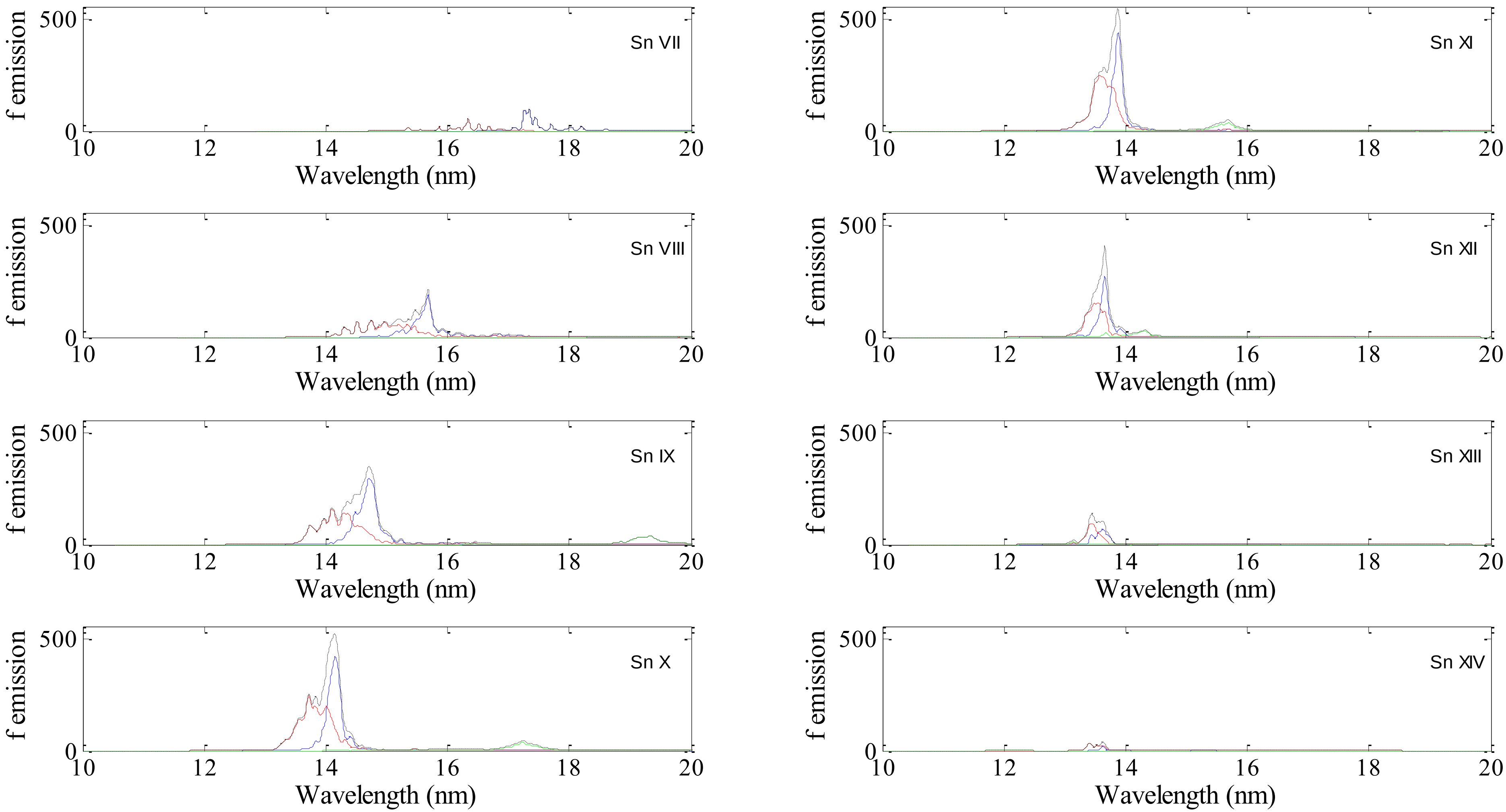
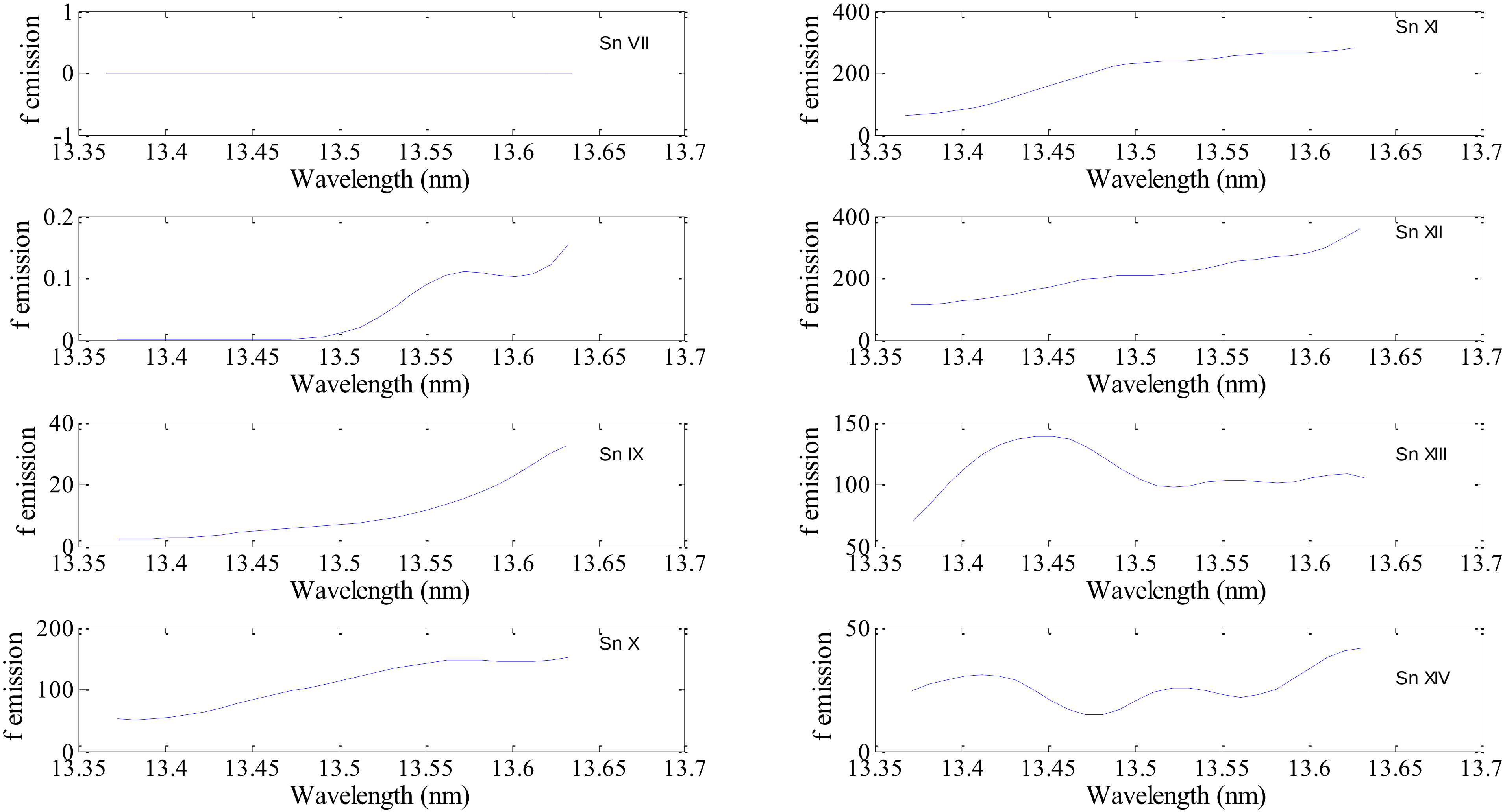
Sn UTA (Unresolved Transition Array)

R. Cowan, The Theory of Atomic Structure and Spectra, University of California Press (1981)



blue 4d-4f, red 4d-4p, green 4d-5p sum of all three is the black dashed

Sn Inband



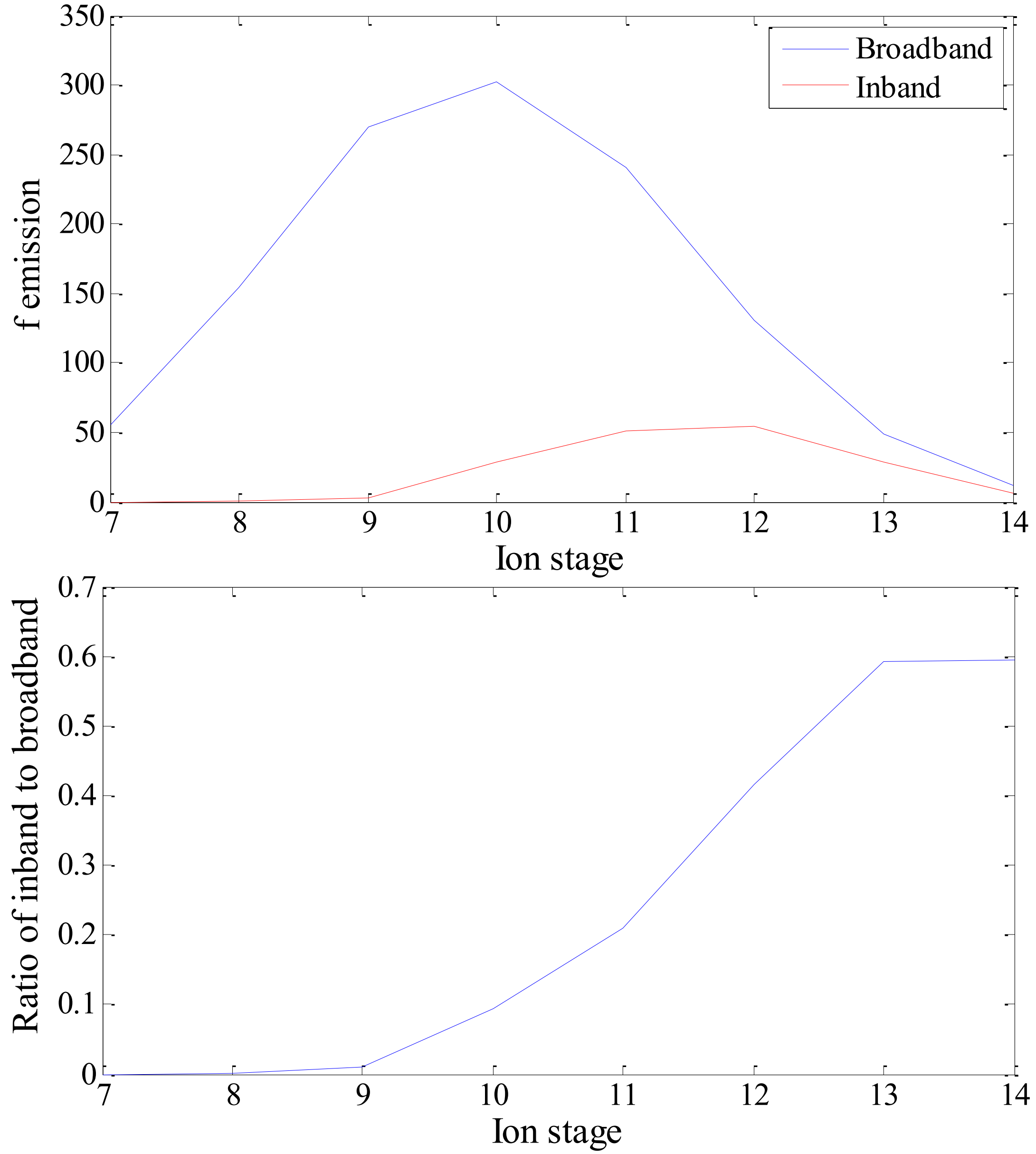
Assume we can not discriminated amongst the UTA, so Intrinsic Conversion Efficiency is the ratio of inband to out-of-band

Sn Inband Efficiency

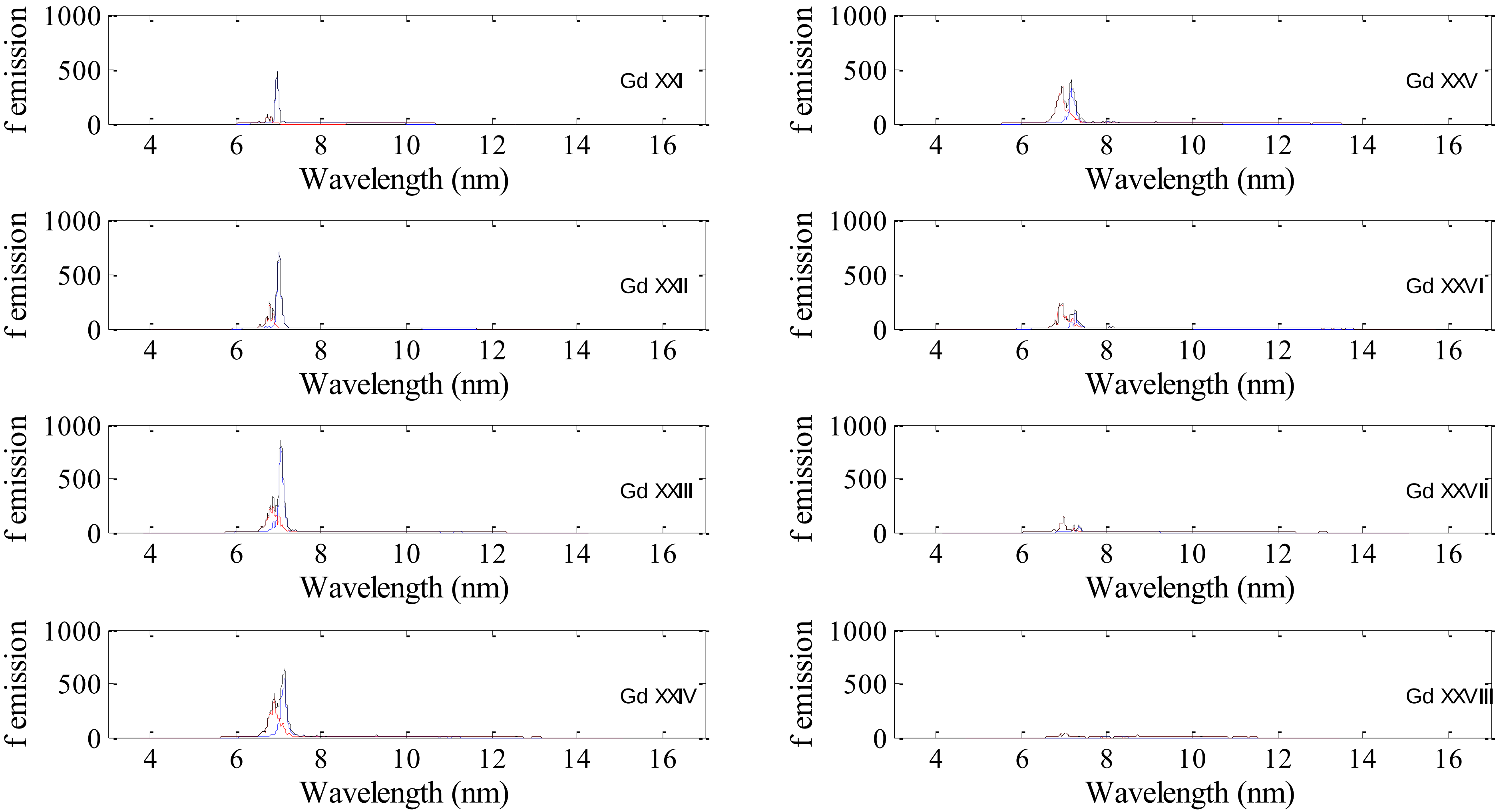
Sn XII is the brightest inband
(2% bandwidth @13.5 nm)

Sn XIV is the most efficient
(60 %)

Sn XII 42% efficiency



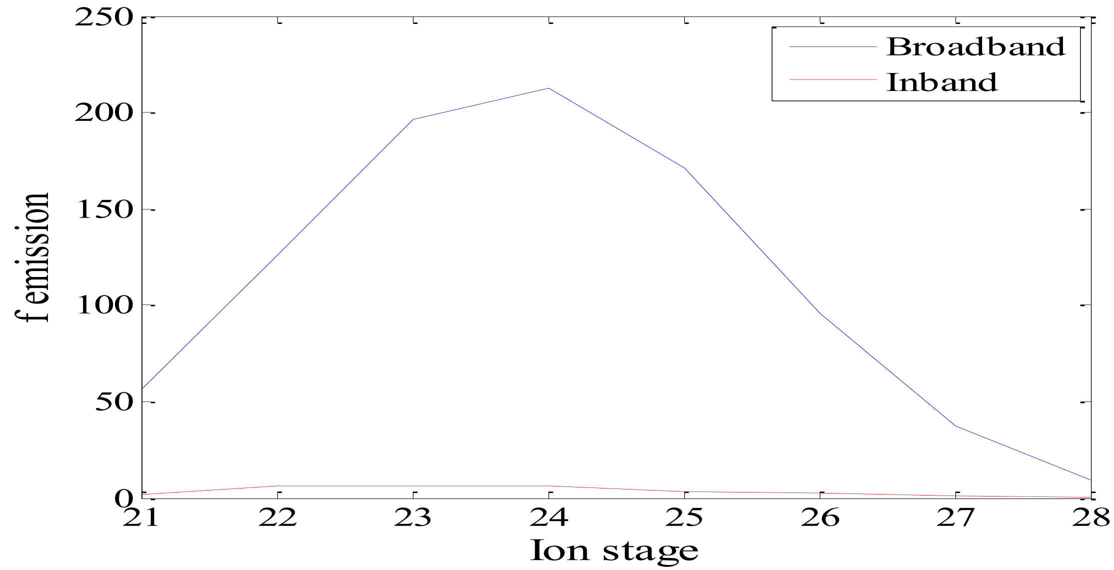
Gd UTA



blue 4d-4f, red 4d-4p sum of all is the black dashed

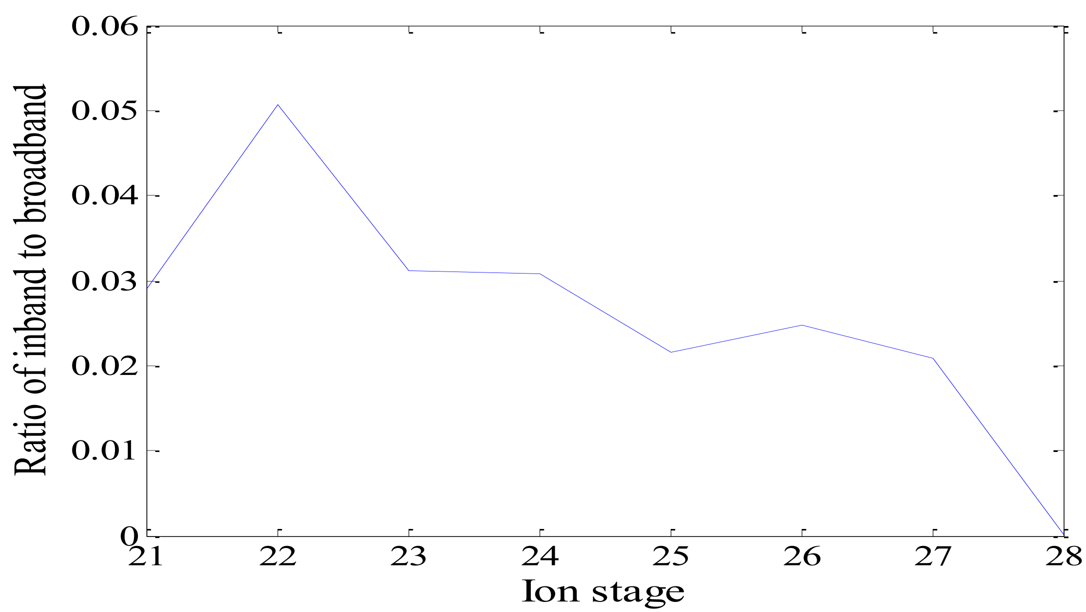
Gd Inband Efficiency

Gd XXIV is the brightest inband
(0.6% bandwidth @ 6.78 nm)



Gd XXII is the most efficient (5%)

Gd XXIV 3% efficiency

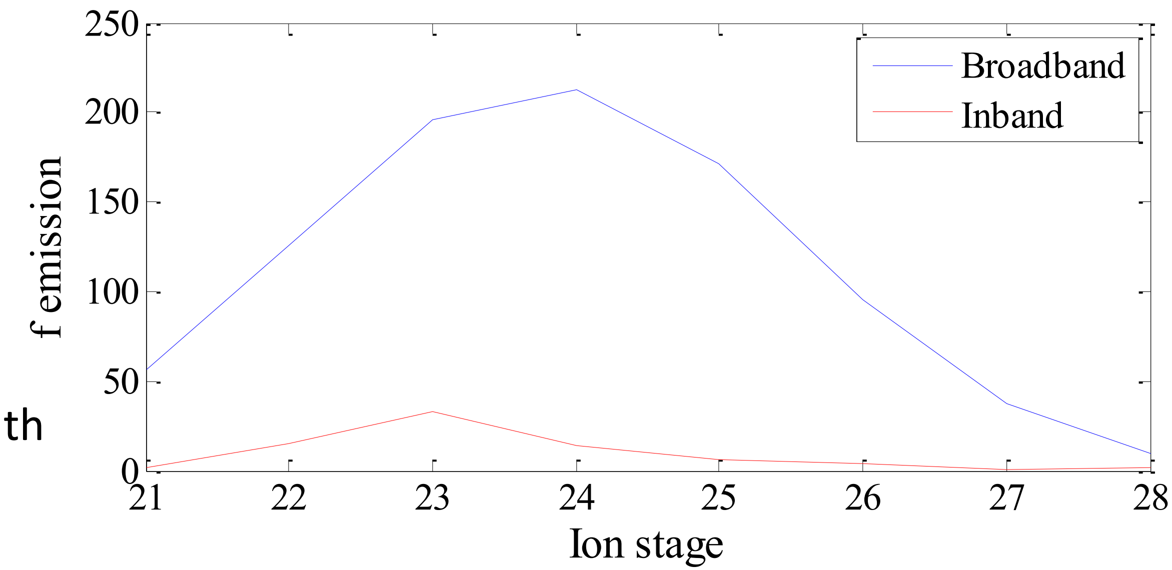


Gd Inband Efficiency

Only 4 upper configurations included and only two inband
Scaling factors fixed

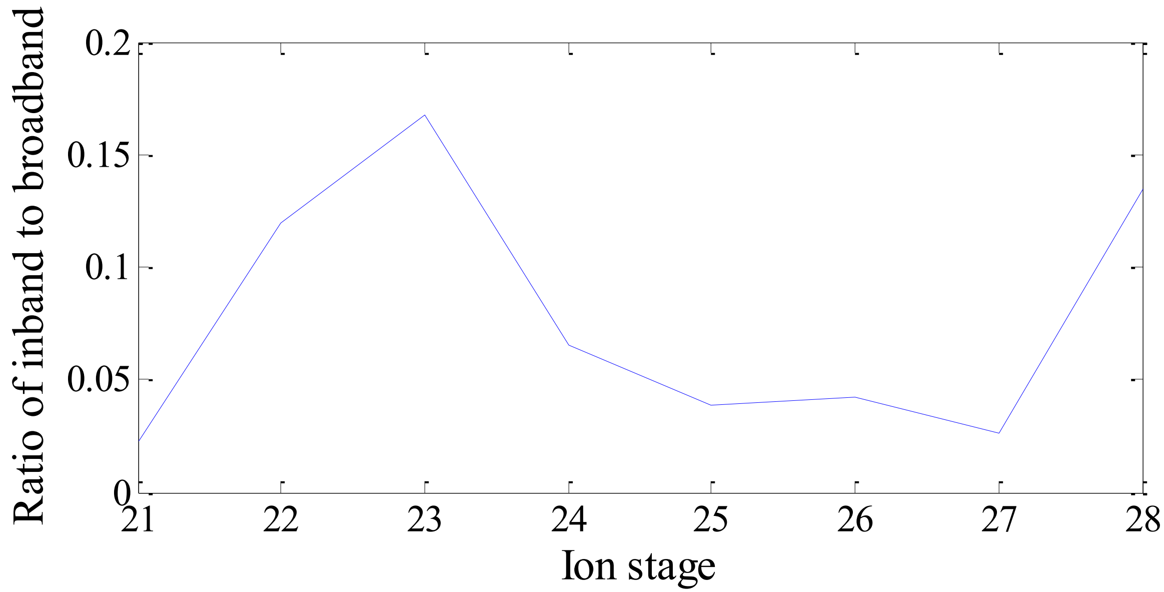
To give a better idea:
Shift mirror to peak of UTA,
(7.06 nm) keeping a 0.6 % bandwidth

Gd XXIII is the brightest inband.



Gd XXIII is the most efficient (16 %)

Gd XXII (46%) if a 2% bandwidth is used



Power Densities Required

Sn

~1.2 x 10^{11} Wcm^{-2} for Nd:YAG [P. Hayden *et al., J. Appl. Phys.* ***99,*** *093302* (2006)]

~1 x 10^{10} Wcm^{-2} for CO_2 [S. Fujioka, *et al.*, *Appl. Phys. Lett.* **92**, 241502 (2008)]

Gd

~4 x 10^{12} Wcm^{-2} for Nd:YAG [T. Cummins, *et al.*, *Appl. Phys. Lett.* **100**, 061118 (2012)]

This corresponds to ~ 4x 10^{11} Wcm^{-2} for CO_2

To get this: x3.8 laser energy
x0.52 spotsize
x0.27 pulse width

For the case where the laser energy is increased:
3.8 x 16%(max. Gd efficiency)=60.8%, similar to the Sn case, but half the number of photons

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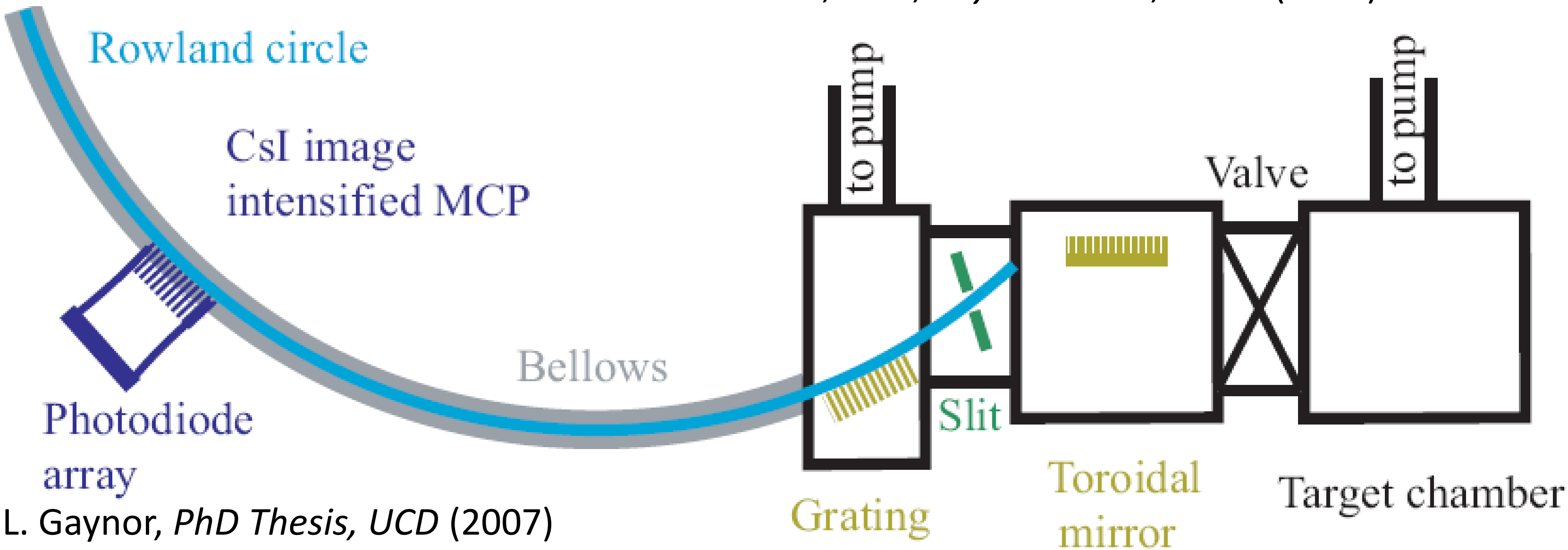
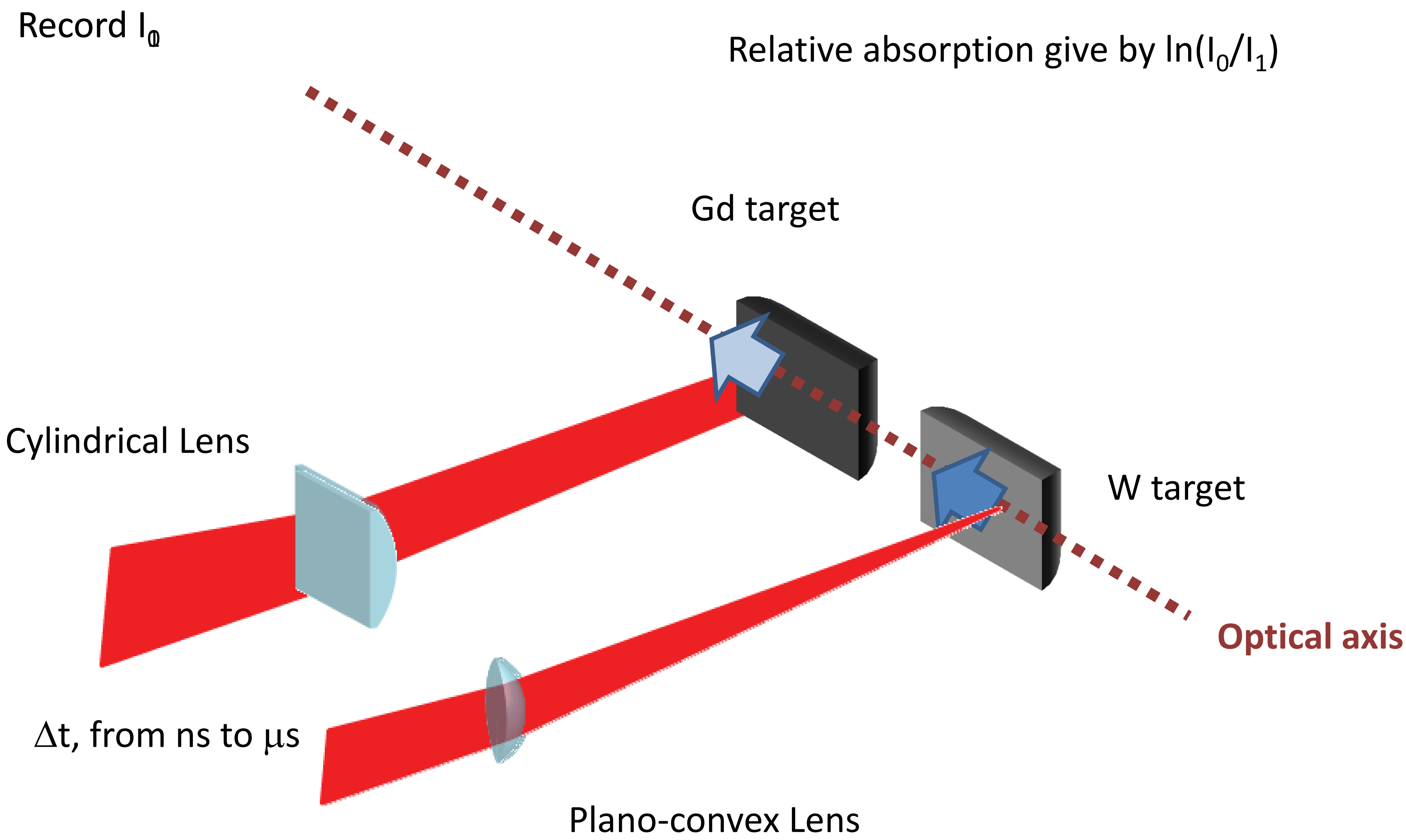
DLP Photoabsorption

J. T. Costello, *et al*, *Phys. Scr.* **T34**, 77-92 (1991)



L. Gaynor, *PhD Thesis, UCD* (2007)

DLP Photoabsorption



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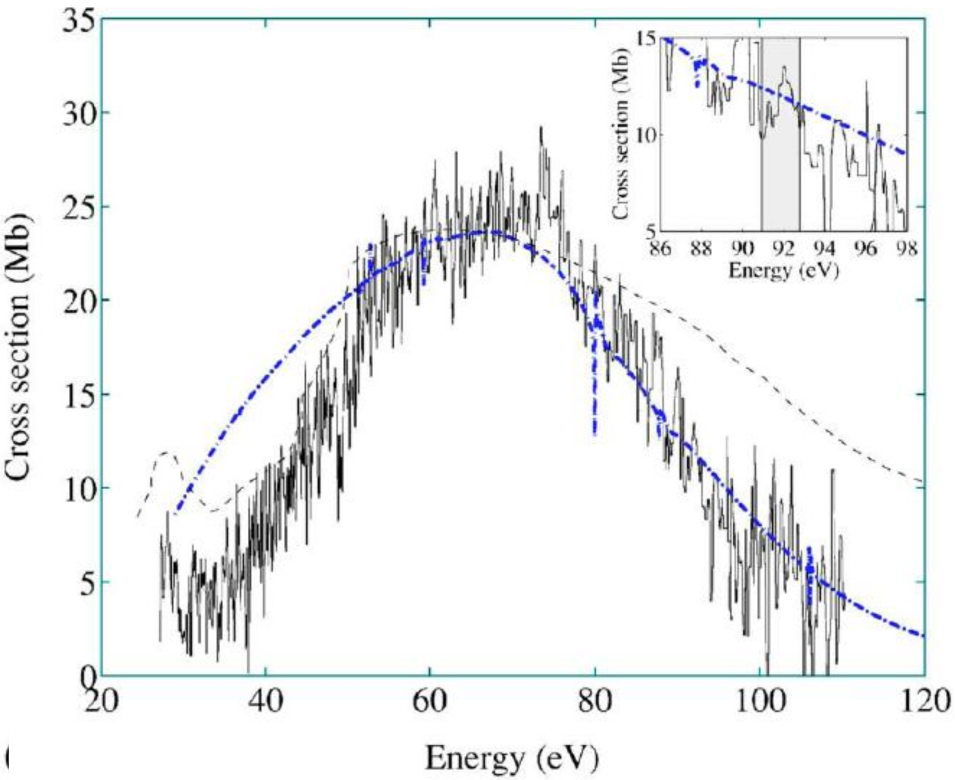
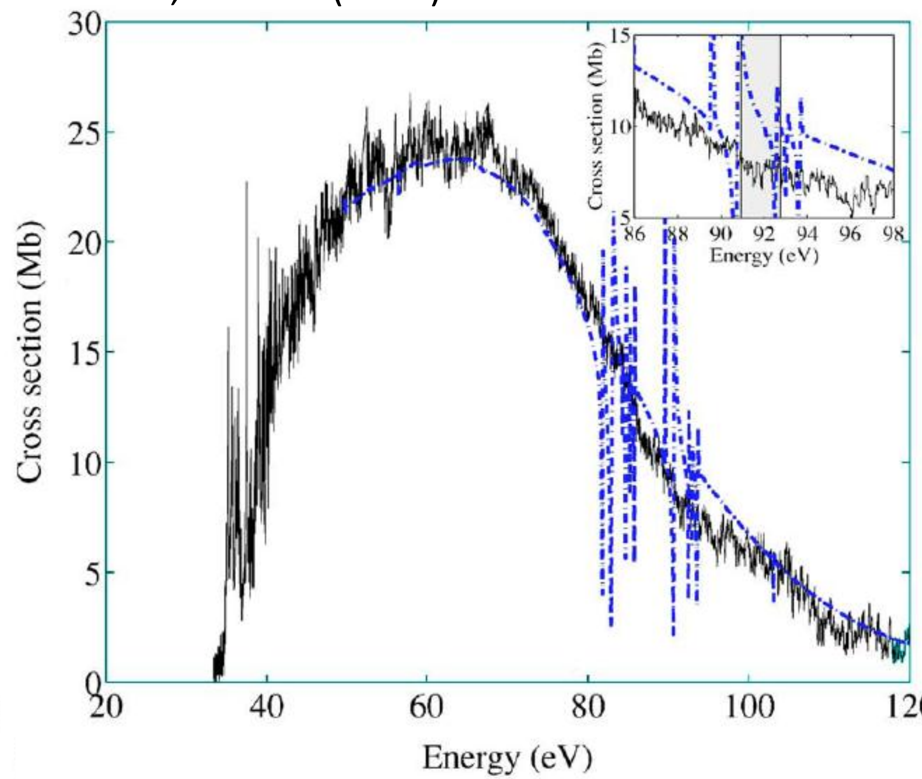
Previous Results for Sn

M. Lysaght, *et al.*, *Phys. Rev. A* **72**, 014502 (2005)





Absolute 4d −εf shape resonance cross sections (**9–12 Mb**) determined by comparison to relativistic time dependent local density approximation (RTDLDA) calculations [D. A. Liberman, A. Zangwill, *Comp. Phys. Comm.* **32**, 75 (1984)], for Sn and a range of similar elements.

"the measured cross sections appear to be smaller than predicted especially at the peak cross section"

"reproduced the cross section profile extremely well once the energies were shifted by a constant amount 1–10 eV"

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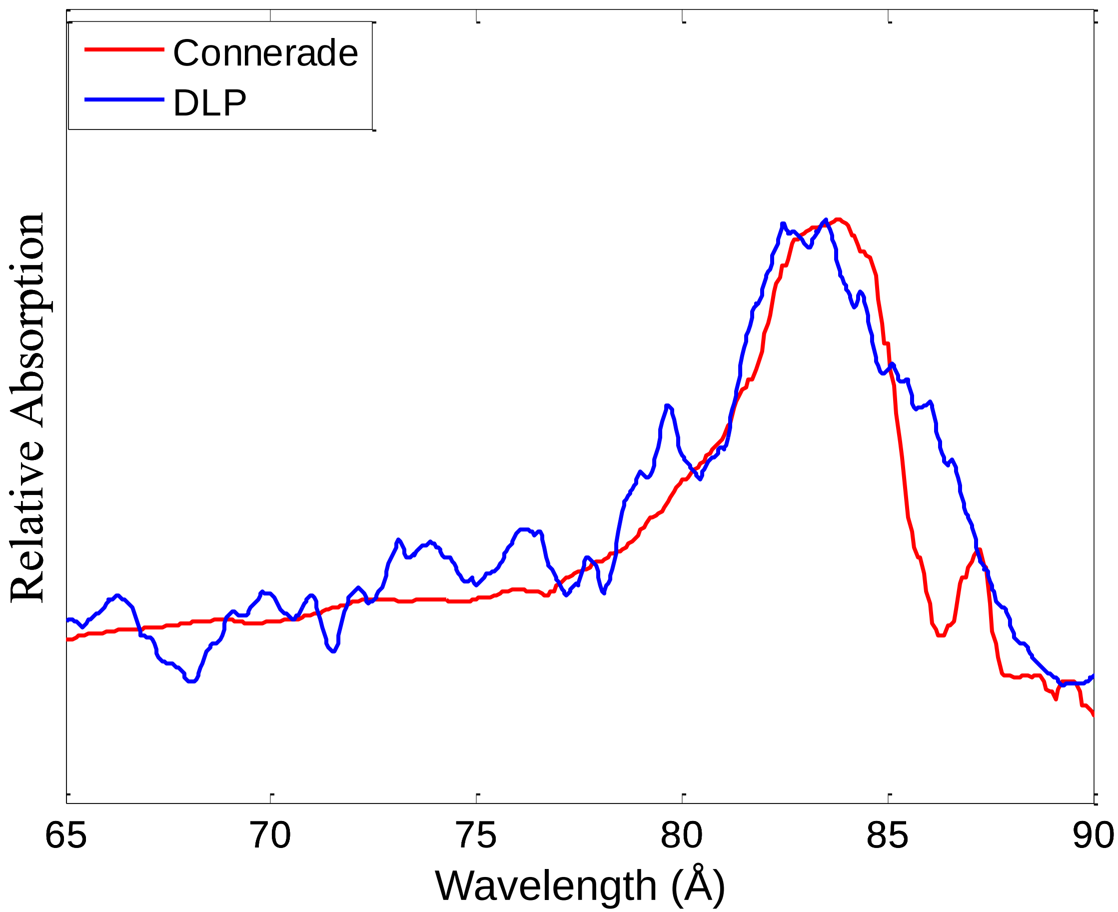
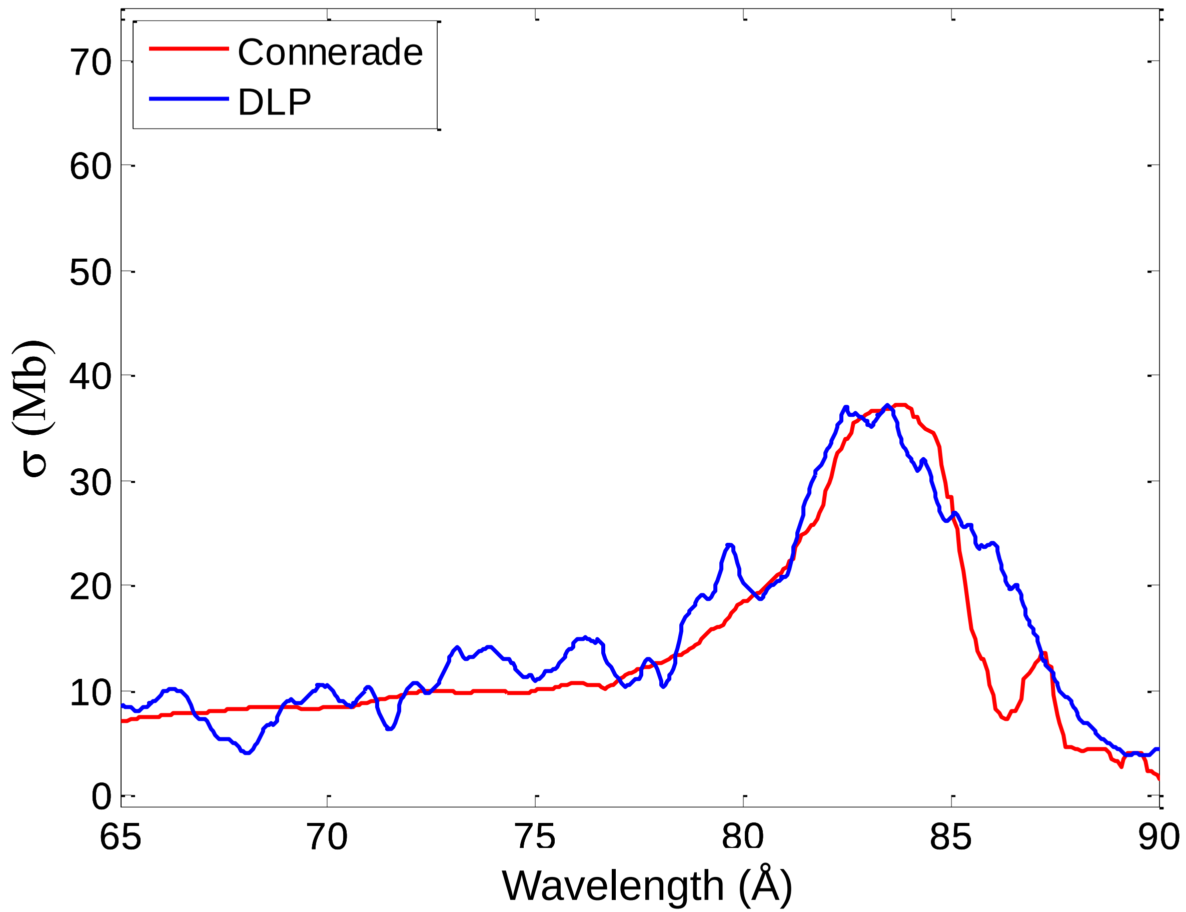
DLP Photoabsorption for Gd I

J. P. Connerade and M. Pantelouris, *J. Phys. B: At. Mol. Phys.* **17**, L173 (1984)



Mainly 4f −εg shape resonance, along with 4d −εf and 5p −εd

DLP Photoabsorption for Gd I



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Summary

- Similar emission f values for Sn and Gd
  - Ratio of inband /out-of-band higher for Sn (42% vs 3%)
  - 6.x nm, define x (ratio up to 16%)
  - Maximum bandwidth (up to 46% if 2% bandwidth)
  - Only f values, actual emission will depend on ionisation balance, level populations, radiation transport, etc.

- High power densities needed for Gd
  - One way, by using x3.8 laser energy, should give similar intensities as achieved by Sn today, half the number of photons though.

- Cross sections due to shape resonance in lower ion stages similar for Sn and Gd ~7–12 Mb.
  - Improved experimental and calculated data to be published soon

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